four times, so as to make the scale of the map about three times, that of Angström's map. The positives thus made are then figured, and negatives made from them by contact.

In the negatives so far examined, the scale has been placed within less than $\frac{1}{20}$ Angström division, or $\frac{1}{1000000}$ wave-length of its true position.

As to the definition, much is lost in the enlargement, not so much from want of definition in the enlarging lens, a 25 by 21 inch Dallmeyer, rapid rectilinear, as from the radical defect of photographic processes; for, when one brings out the fine doubles in which the streak of light in the centre is very faint, he loses many of the fainter lines. The original negatives show E, and even finer lines like that at wave-lengths 5276.1 and 5914.3, plainly double, but there is little hope of showing this on the map.

The atmospheric line just outside of one of the D lines also nearly merges into it, although in the original negative it is widely sundered from it.

However, there are few instruments which will show more of the spectrum than can be found on the map, even below the D line, where cyanine and chlorophyl plates had to be used, for the first line in B is shown widely triple. Above, and including the D line, the definition rapidly improves, and a low-power magnifier must be used to bring out the full definition. However, from wave-lengths 5300 to 3800 the superiority over the old edition is not so marked as above and below this. In the ultra violet above H there is an immense improvement in the new, both in definition and in the quality of the photograph.

As to comparison with other maps of the spectrum made by measurement and drawing, it may be said that no comparison is possible. The photograph is the work of the sunlight itself, and the user of this map has the solar spectrum itself before him, and not a distorted drawing full of errors of wave-length and of intensity. The superiority is so great that there is no possibility for comparison.

The following is a list of the plates, each 3 by 2 feet, containing two strips of the spectrum: *a* includes from wave-length (?) to 3350; *b*, from wave-length 3270 to 3730; *c*, from wave-length 3670 to 4130; *d*, from wave-length 4050 to 4550; *e*, from wave-length 4450 to 4950; *f*, from wave-length 4850 to 5350; *g*, from wave-length 5250 to 5750; *h*, from wave-length 5650 to 6150; *i*, from wave-length 6050 to 6550; *j*, from wave-length 6450 to 6950.

Negatives *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, are now ready, although that for *i* is too irregular to be entirely satisfactory, and it may be replaced. The plate *a* to the extremity of the solar spectrum will be attempted this summer, but may cause much trouble and delay, and will be sold as an extra plate. The prints are on heavy albumen paper mounted on cloth.

The cost of printing has been so much increased that the prices for this new series will be greater than for the old one, but scarcely more than covers the cost of the printing.

The plates will be delivered in Baltimore or New York, or will be sent by express or mail, securely packed, at the charge and risk of the purchaser, at the following net prices: set of nine plates, wave-length 3270 to 6950, $18; single plates, $2.50. Should any extra plates continuing the spectrum in either direction be published, subscribers can have them at $2 each. Subscribers to the old edition will have the preference in the delivery of the new one, and a reduction of 10 per cent in the price. The three plates *h*, *i*, *j*, to complete their set, will be furnished for $6. They are advised to take *g* also, as the old map of that region was bad. The four, *g*, *h*, *i*, *j*, will be furnished to them for $8.

Two plates, each 3 by 2 feet, suitable for framing and hanging on the wall, have been made of the B and D lines. The latter are 3 inches apart, and the former has an extent of about 24 inches. Enlargements of some of the carbon bands from the arc electric light have also been made. They show the wonderful structure of these bands, each containing many hundred lines, each one of which is a close double, or, in some cases, a triple. These plates will be sold for $2.25 unmounted, or $2.50 mounted on cloth. No plate will be given away or sent in exchange. Remittances may be made by draft or money-order. All subscriptions and orders should be sent, and remittances made, to the Publication Agency of the Johns Hopkins University, Baltimore, Md.

THE EARTHQUAKE OF LIGURIA, FEB. 23, 1887.

MESSRS. T. TARAMELLI and G. Mercalli have made an exhaustive report on the earthquake of Liguria in February, 1887, to the Italian Department of the Interior. A geological and an historical chapter form the introduction, which is followed by an account of the results of the authors' studies and inquiries. They visited all localities that were severely damaged by the shocks, while information on others, which they were not able to visit, was collected by means of circulars of inquiry. Thus exhaustive reports on the character of the earthquake were obtained from over eleven hundred localities. This abundant material, arranged and discussed systematically, forms the basis and the main part of the report. The results of this discussion are summarized by the *Naturwissenschaftliche Rundschau* as follows: —

Many insignificant, preparatory shocks preceded the Ligurian earthquakes of 1752 and 1854, as well as that of Feb. 23, 1887. In the night from Feb. 22 to Feb. 23, four light shocks were felt over exactly the same territory that was visited by the severe shocks of the following day. Evidently the seismic centre was in full activity that night; but there are only four indications, as no seismic instruments and observers exist on the Riviera di Ponente. A little while before the earthquake began, the sea was observed to be exceptionally quiet. A few observers claim to have seen unusual lights in the atmosphere. In the regions which suffered most severely, animals were observed to be restless. In a very few places a change of springs was observed. Thermometer and barometer were not influenced by the shocks.

The principal shock was observed in a circular area covering about 568,000 square kilometres. Its southern limit is Rome and Mount Ferru in Sardinia. Eastward it extends to Pordenone, westward to Perpignan, and northward to Dijon and Basle. The shocks spread with greater force northward to France and western Switzerland, than southward on the Italian peninsula. According to the intensity of the phenomena, the authors distinguish four zones; the central region, in which the most formidable destruction took place, forming a zone a hundred kilometres in width along the coast from Mentone to Albissola. It embraces a narrow coast strip, because the seismic centre was situated in the sea, and because the old crystalline rocks of the Ligurian Apennines reflected the seismic waves. The next zone is called by the investigators the "almost destructive" one. It extends to the hills of Piedmont. Very strong shocks were felt in the third zone, which extends from the second principally north-westward, including Turin and the low-lying Canavese, where the shocks seem to have been increased in violence by waves reflected from the gneissic mass of the Grand Paradiso. The last zone embraces those places in which the earthquake was felt, but did not do any damage.

In the whole territory where the earthquake was strongly felt, the first shock lasted thirty seconds, and consisted of two shocks almost immediately following one another. Each of these shocks caused first a subsultory, then an undulating motion. In no place, not even in those where the shocks were most destructive, was the movement vertical. Therefore the resultant of both shocks was much influenced by local causes, and neighboring places show great differences in the direction of the shocks. The second shock was the stronger one, causing particularly a strong subsultory movement. Only in Nice and other places in France the first shock was the strongest. The second part of the shock was everywhere complicated by the resultant action of its combination with the first shock. This accounts for the fact that the second shock frequently left the impression of a rotatory movement. In many places, for instance in Mentone, objects lying on the ground have been turned round. In places lying at greater distances from the central point, the vertical component decreased rapidly, but all the other peculiarities of the shock remained. In the outlying zone the slowness and regularity of motion of the shock were remarkable, which caused pendulums three feet and more in length to swing.

At various places the horizontal velocity caused by the shock was determined by observations, and by objects thrown some distance. At Oneglia the force was large enough to give a portion of a sill, weighing about five thousand pounds, an initial velocity of thirty-one feet. This horizontal force decreased with increasing distance

from the centre. At Taggia it was twelve feet; at Nice, fifteen feet.

In many places of the region where the earthquake displayed its greatest power, some observers claim to have heard a noise preceding the motion. To some it seemed to be similar to the rattling of a train; but it is more generally compared to the howling of a hurricane, or to the rattling of a cart rolling over a stone pavement, or to distant thunder. Even in the third zone there are numerous places in which the noise was heard before or during the shock. In the fourth zone it was noted in very few places. In several places in the province of Porto Maurizio a subterranean noise was all that was observed; it was not followed by any movement.

Great care was given to the determination of the direction of the first shock. The methods applied were to inquire into movements of lamps and other hanging objects, the stopping of pendulum clocks, the removing or falling of objects, and the destruction of buildings. This part of the investigation showed, that in the whole region of the Ligurian Apennines, which was shaken most violently, all directions were equally frequent. This fact suggests the existence of an elongated epicentre parallel to the Ligurian coast. East of the meridian of Oneglia, directions between east-north-east to west-south-west and north-east to south-west prevailed. West of this meridian the greater number of waves were in the directions from east to west and from south east to north-west. In many places the direction of the movements changed once or twice during the first shock. Thus movements resulting directly from the shock, and secondary waves, could readily be distinguished. In many cases, among the various directions, two were prevalent which were vertical on one another.

A remarkable phenomenon was observed in the valley of Padua. The direction pointing towards the centre of the disturbance existed only during the latter part of the shock. In the beginning the crystalline rocks of the West Alps, which were shaken a few moments before the neighboring recent deposits, deflected the waves towards the arc of the valley of Padua, giving them an east and west direction.

If all important directions of shocks are marked on a map of western Liguria, they will be seen to converge in the sea between Oneglia and St. Remo about fifteen or twenty-five kilometres south of the coast. Therefore this is the probable place of the epicentre. The same place results from a study of the isoseismic lines which are concentric to a point twenty kilometres south of Porto Maurizio. A secondary centre seems to have been in the sea south of Nice.

A comparison of the most trustworthy reports shows that the Ligurian coast between Nice and Laona was struck by the great shock at 6.20 A.M.: therefore the shock must have reached the epicentre a little before this time, probably at 6.19 A.M. If this movement is considered the beginning of the shock, and the time of the disturbances observed at other places is compared to it, it appears that the velocity of transmission was not equal in all directions. It was greater to the west, being 4,762 feet in the direction of Marseilles and Nice, and only 1,916 feet in that of Genoa. This difference is probably not real, as the first shock of Nice seems to have originated at a secondary epicentre south of Nice, the existence of which was known through the earthquakes of 1564 and 1752.

Only in a few places was it possible to ascertain the vertical angle of the shock with any degree of exactness; but the value of 40° seems to be well assured by observations between St. Remo and Albenga. Based on these observations, and on the fact that this angle decreased with increasing distance from the epicentre, slower than it did in the great Andalusian earthquake of Dec. 25, 1884, the seat of the centre was found to be at a depth of eighteen kilometres, while that of the secondary centre south of Nice was somewhat less. It seems probable that the shocks preceding and following the most violent one also proceeded from the main centre, but that the first originated in a greater, the later in a less depth. The centre seems to have approached the surface during the seismic phenomena.

The violent shock was felt at sea between Corsica and the western Riviera by several vessels, which were shaken in all directions, the impression being that they had struck a rock. Almost everywhere on the Riviera the sea fell a little at the moment of the first shock, and suddenly returned to its former level, without the destructive waves which have followed other earthquakes. Some observers maintain that the falling continued several days after the earthquake, while at Laona and Porto Maurizio a change of level is said to have taken place. No rise is said to have followed the first fall. At Nice, St. Remo, and Savona dead fish were collected after the earthquake. According to Bellotti, all of them were deep-sea fish: therefore it cannot be doubted that violent shocks occurred in considerable depths near the coast of Liguria. This confirms the opinion that the centre must have been under the sea.

The earthquake did not cause any important changes in the topography of the affected region, and all of them must be considered dynamical effects of the tremors upon the surface strata which were broken or slightly moved. None of the resulting changes are connected with the prime cause of the earthquake. No atmospherical phenomena proving the presence of an extraordinary amount of atmospheric electricity were observed. In this respect the Riviera earthquake differed from that of Andalusia.

About nine minutes after the first shock a second one followed, violent and long; then at 8.53 A.M. (Rome time) a third one, short, but almost as violent as the first, and very destructive in its effects. Both these shocks were felt slightly in the whole region disturbed by the first one. In the central zone about twenty-two shocks more were felt in course of the 23d and in the following night. Only one, at 2.20 P.M., was strong. After the 23d the number of shocks decreased; but they continued until March 11, when the most violent shock since the first three was felt. At Savona, between Feb. 23 and March 11, about fifty distinct shocks were felt. Only the shocks of Feb. 23 were destructive. Six hundred and forty persons were killed, and about as many wounded. The damage in the province of Porto Maurizio is estimated at $2,600,000; in the environs of Albenga and Savona, at $1,700,000. No detailed estimates are available from the French districts.

NATURE AND ORIGIN OF PHOSPHATE OF LIME.[1]

THE circumstances which have led to the preparation of the subjoined report on mineral phosphates are as follows: viz., in 1870 the present writer was employed by the superintendent of the Coast Survey, the late Benjamin Peirce, to examine the phosphate beds of South Carolina with a view to determining the limits of that field; it was also deemed desirable to ascertain, if possible, the conditions which led to the formation of the deposits.

It was at that time the intention of Professor Peirce to have the geology of the belt of country within the limits of the Coast Survey maps carefully determined, so that they might be shaped in a way that would better serve the commercial interests of the country, and also have a greater scientific value. After a time it appeared that there were legal difficulties in the way of publishing these studies in the reports of the Coast Survey, and this work was suspended. It was the hope of Professor Peirce to secure a modification of the law; but before this was accomplished, he retired from the post of superintendent, and his successor deemed it best to abandon the project. During the two years in which I was engaged in this work on the geology of the coast line, I became very much interested in the problems connected with the origin and distribution of phosphatic deposits. From 1873 to 1880, while employed as State geologist of Kentucky, I had a chance to see a good deal of the somewhat phosphatic limestones of the Cambro-Silurian sections, — a set of beds which, by their decay, have given great fertility to the soils that lie upon them. The researches of Dr. Robert Peter, the chemist of that survey, made it plain that the phosphatic contents of the soils are among the first materials to be exhausted by the careless tillage which characterizes our American agriculture, and that they are the most costly to restore to the soil.

Extending the general inquiry to the grain-producing districts which lie to the north and west of Kentucky, it became evident that all those States which are now the granary of this country, and the chief source of supply for European markets as well, are rapidly exhausting their soils, and will soon be in grave need of

[1] Portion of an introduction, by N. S. Shaler, to a forthcoming bulletin of the United States Geological Survey, prepared by R. A. F. Penrose, jun.